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ASTRONAUTICS

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PRODUCTION ENGINEERING DEPARTMENT
MANUFACTURING DEVELOPMENT
SECTION 490

REPORT GD/A-AKM64-032

RADIATION SHIELDING FOR CENTAUR AFT BULKHEAD

MD PROJECT REPORT
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ABSTRACT

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This report describes fabrication of a lightweight radiation shield for the Centaur aft bulkhead.

The assembled shield has a diameter of approximately 10 feet and is comprised of 12 gore sections. Specific characteristics required were low weight, high weight/strength ratio and good radiation qualities in specific wave length areas. This shield system was designed as an improved replacement for the existing production shield system.

Specimen gore sections were successfully fabricated using a lightweight sandwich structure of two layers of four-mil thick phenolic preimpregnated glass cloth sandwiched between two one-mil thick plastics film skins. The external film is a white pigmented Polyvinyl-Fluoride (PVF) film and the inner skin is an aluminized (both faces) polyester film.

This system resulted in an improved product with a weight savings of approximately 16 lbs per missile. The cure cycle fabrication time was trimmed from 3-1/2 hours to 1 hour.

author

Copies of this report are available on request to Technical Services, Section 490-3, Extension 671.

TITLE

RADIATION SHIELDING FOR CENTAUR AFT BULKHEAD

OBJECTIVE

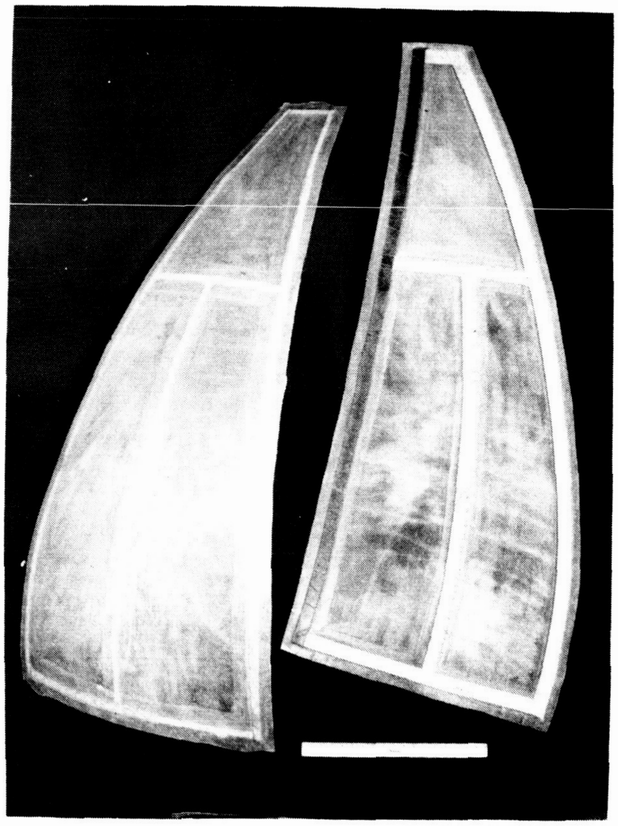
To develop an improved radiation shield system for the Centaur aft bulkhead.

INTRODUCTION

The aft portion of the Centaur LO_2 tank is subjected to solar radiation following its separation from the first stage Atlas vehicle. A protective shield for covering the entire Centaur aft bulkhead is necessary to minimize LO_2 boil-off, in order to preserve fuel for re-ignition and flight.

Engineering Tank Structures Group, Section 961-8, requested our participation in a program to develop a more efficient and lighter weight radiation shield to protect the aft bulkhead during second-stage flight. The shields (Fig. 1) used prior to this development program were fabricated of reinforced fiberglass with honeycomb stiffeners. The inside surfaces of each gore were painted with aluminum paint and the outside surfaces painted with a white epoxy paint.

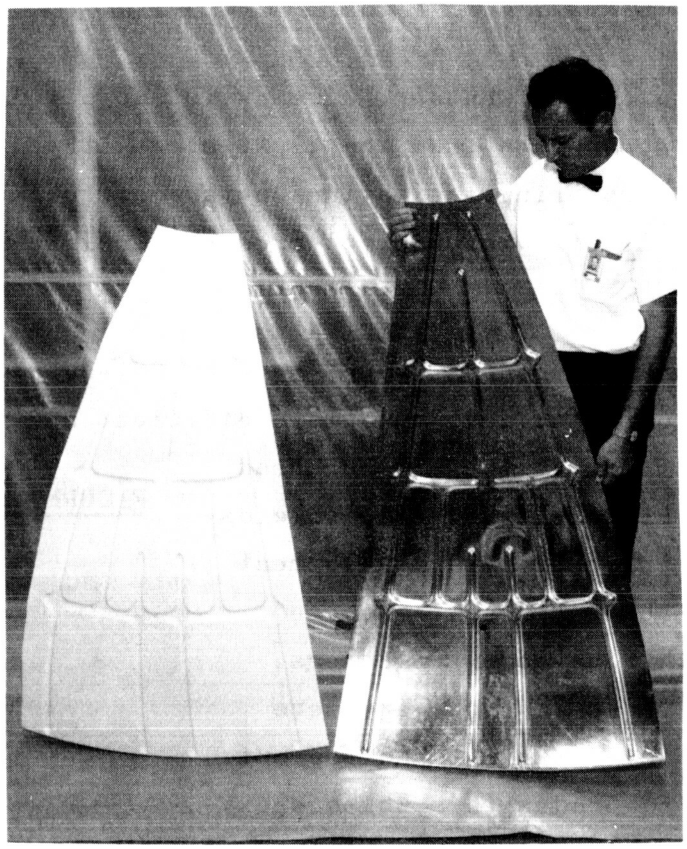
FIGURE 1. PREVIOUS RADIATION SHIELDS (unpainted)



CONCLUSIONS

Lightweight radiation shield gore sections (12 per missile) having a compound curvature with built-in stiffeners were satisfactorily constructed (Fig. 2) using two layers of phenolic impregnated glass cloth sandwiched between two layers of one-mil thick film skins.

FIGURE 2. NEW REINFORCED PLASTICS FILM RADIATION SHIELDS



RECOMMENDATIONS

1. An evaluation program should be initiated to improve the formability of the aluminized film skin. A more flexible film would reduce or eliminate wrinkling of the aluminized film skin.

2. Higher quality control standards should be applied to purchase of aluminized film to ensure an opaque aluminized film rather than a translucent film.

DISCUSSION

It was decided to evaluate aluminized polyester film as the inner reflective surface bonded to two layers of phenolic, epoxy, or polyester preimpregnated glass cloth. It was also decided that the outer surface of the shield would be painted with the same type of white epoxy paint that was used on the previous shields. This method of painting the outer surface was later abandoned in favor of another thin film (white pigmented Polyvinyl-Fluoride)(PVF). Stiffeners were to be included in the shields by forming beads in the polyester film, then filling them with a low density rigid polyurethane foam and covering the flat section of the bead with resin preimpregnated glass cloth and the PVF outer skin film.

PROTOTYPE TOOL DEVELOPMENT AND FABRICATION

A fabrication feasibility study was made to determine materials and processes compatibility. For this study a 24 x 24-inch plaster pattern was made with stiffener beads included. The pattern design and contours were similar to those being drafted for B/P release. A male plastic mold was made with female beads. This tool was used to vacuum form the aluminized polyester to shape, including the beads. A copper vacuum line was bonded on the underside of the mold along the beaded areas and small holes (No. 60 drill size) were drilled into the vacuum line from the inside of the mold. The holes were drilled at the ends of each bead and every three inches along the bottom of the bead. These holes allowed vacuum pressure to draw the film into the beaded areas.

FABRICATION OF FIRST PROTOTYPE SHIELD

A piece of the aluminized polyester film was placed in position over the plastic tool. The film was clamped around the outside periphery of the tool prior to applying vacuum. The tool with film in place was put in an oven set at 450°F. When the tool had been in the oven for three minutes, vacuum was applied and the film was drawn tightly against the tool. The tool was removed from the oven when the vacuum gage indicated full pressure was being applied. The tool and part were allowed to cool to room temperature while under vacuum pressure. Two layers of polyester preimpregnated glass fabric were layed up over the film while the film was still under vacuum. The first layer of glass fabric was applied only in the beaded areas including 1/2-inch of bead flange. A polyurethane foam (2-lb density) was poured into the beaded areas and then sanded smooth to match the outside contour. The second layer of preimpregnated glass fabric was then applied over the entire part. Another layer of aluminized polyester film was put in place over the glass cloth and another vacuum line was used to draw vacuum between the two films. The part was cured out for one hour under vacuum in an oven set at 275°F. After the part was removed and cooled to room temperature, it was noted that the films were bonded fairly well but the inner laminate strength of the polyester prepreg was poor. There were voids about 1/4-inch in diameter at the ends of each bead and occasionally in other parts of the beads. The void problem in the beaded areas occurred throughout the early development stages of this project but was later eliminated by puncturing the inside skin at each end and every three inches along the bottom of the beads to eliminate the necessity of the second vacuum between the two films. In this way all of the pressure was directed down on the top film and any gas between the two films was forced out through the pin holes in the inside film.

DISCUSSION (contd)

FABRICATION OF SECOND PROTOTYPE PART

The second prototype part was fabricated the same as the first except a room-cure tape adhesive system was evaluated as a substitute for the polyester prepreg. The resultant part was too heavy and too flexible.

FABRICATION OF THIRD PROTOTYPE PART

The third prototype part was fabricated by the same procedures used in the first and second parts. The difference was that a phenolic prepeg glass cloth was evaluated as the bonding media. The resultant part was light in weight, rigid, and well bonded. This system is the one selected for fabrication of the full sized production prototype.

A fast cure cycle proved most satisfactory when using the phenolic adhesive system. The fast cure restricted the resin flow by rapidly setting the adhesive before it could flow excessively. This was done to minimize the amount of resin flowing through the pin holes in the aluminized skin. The cure cycle for this system was established at 300 $\pm$ 5°F for 1-1/2 hours or 340 $\pm$ 5°F for one hour.

FABRICATION OF THE FOURTH PROTOTYPE PART

Early in the development program an improved outer skin radiation coating was being considered to eliminate the white epoxy paint operation. The physical and chemical characteristics of PVF (polyvinyl-fluoride) film were attractive if the radiation requirements could be met. A sample of the film was sent to the Thermodynamics Engineering Group, Section 966-3, for evaluation. They approved the use of the film.

The PVF film formed and bonded well to the phenolic prepreg. The film was layed over the prepreg, vacuum was applied to draw it tight against the prepreg, and a 500°F heat gun was used to assist in drawing the film into the beads. The system was then cured out in an oven set for the phenolic cure cycle.

The polyurethane foam which was used to fill the beads proved to be quite unstable. Since it shrank during the cure cycle, and was difficult to control its density, it was decided to evaluate bead stiffeners without foam cores. The fourth prototype part was made without foam in the stiffeners and proved strong enough to meet engineering requirements, therefore, the foam core was eliminated.

All of the parts made on the small development tool had a few wrinkles in both films due to the absence of any stretching action on the films except in the beaded areas. The development tool was not altered because it was planned that the production tool would be designed to employ a stretching action on the film which would eliminate wrinkles.

PRODUCTION TOOL DEVELOPMENT

Production tools were ordered in February and the first tool was made available to Manufacturing Development in May. The tool was a high temperature plastic tool (422 Epoxy System by Fiberresin Co.,) with a reinforced plastic vacuum ring made with a cast-in-place silicone rubber gasket (RTV-60 by General Electric) which performed well during production of parts.

A piece of aluminized polyester film was applied to the tool so that initially there were no wrinkles present. The vacuum ring was put in place to hold the film in that position and vacuum was applied. The

DISCUSSION (contd)

film drew down perfectly to the point where it started to enter the deep draw area. As it drew into the deep draw area the film became very thin and finally reached its elastic limit point and ruptured along the entire length of the deep draw area. This deep draw area was necessary in order to form a one-inch angle at the aft end of the shield.

A second film was prepared by the same procedure but the film was formed in an oven set at 450°F in an attempt to soften the film so that it would stretch farther. The film ruptured in the same area as did the one formed at room temperature.

A third film was prepared by the same procedure except the deep draw area was filled with dry glass fabric thereby eliminating the angle. This was done to determine if a part could be made without rupturing if the deep draw area was eliminated. The film drew down perfectly and bottomed out on the tool. Although a completed part was not made with the angle eliminated, it was assumed that an excellent part could be made by applying the angle in a secondary bond operation.

Further development effort was made to include the angle in the forming operation. It was found that by applying the film loosely to the tool prior to vacuum forming, the angle could be included; but many wrinkles were formed in the film.

The Centaur need date deadline was rapidly approaching, so it was decided by our section and engineering to fabricate the first ship set of parts with the film loose enough to allow it to be drawn into the deepest area of the tool regardless of the wrinkles, which are more of a problem in aesthetics than one of function.

Production Part No. 1:

The first production part had many wrinkles in the aluminized film but the phenolic prepreg and the PVF film flattened them out so that all that was evident on the aluminized side of the film was a thin crease line. Wrinkles in the PVF were not as numerous but were more evident because they were not flattened but remained standing up to a height as much as 3/16 of an inch. All of the beads in this part were fully drawn to shape but there were some wrinkles in the beads.

Production Part No. 2:

The Design Engineer was called for consultation and observation of forming methods on part No. 2. This part was made using the same methods as part No. 1. Engineering decided to accept all parts for production and would make allowances for the presence of wrinkles as long as they were not excessive.

The fabrication of the first two parts made it evident that a parting agent of some type was necessary on the aluminized film to prevent the phenolic resin, which had flowed out through the punctured holes in the film during oven curing, from bonding tightly to the aluminized surface. When this resin flow-out was removed from the film it pulled the aluminizing from the film. The use of a parting agent eliminated this bonding action.

Process Evolution:

The manufacturing process evolved during the fabrication of the first six parts to a point where all of the originally encountered problems had been solved except the wrinkle problem. This problem was minimized by the 12th part. It was found that as the aluminized film is being

DISCUSSION (contd)

Process Evolution: (contd)

formed; it is best to (1) start with the film in a wrinkle-free position (taut), and as the vacuum pulls the film into the mold (2) release some of the vacuum ring clamps, especially at the deep draw end of the tool. This controls the amount of film which slips into the mold. This process was developed until wrinkles in the aluminized film appeared only in the area outside the outer bead line and the wrinkles in the PVF film were entirely eliminated by using this process.

Elimination of many wrinkles in the aluminized film was accomplished with a sacrifice of 20% of the bead depth. By applying the film in a stretched position its elastic limit is reached before the film bottoms out in the beads. Engineering agreed that within 20 percent of bottoming out would be acceptable. It also evolved that the aluminized film could be more closely controlled by eliminating the 450°F forming cycle. The film is applied to the tool at room temperature and then drawn into the beads with a heat gun. When the film has been drawn as deep as possible in the beads, a 3/4-inch strip of one-mil aluminized polyester pressure-sensitive film tape is applied to the bottom of the bead to reinforce the thinned out areas which occur during forming. If these areas are not reinforced they tend to split the aluminized film along the beads.

Because of the wrinkle problem in the film-forming operation, another film is being considered for evaluation. This film is an aluminized PVF film which has a greater percentage of elongation and is not as stiff as the polyester. The PVF film bottoms out well in the beaded areas and any wrinkles present have a tendency to creep out or flatten during the cure cycle operation.

Current Production Process:

Forming The Aluminized Polyester Film

1. Clean the forming mold by wiping off (with a clean cloth) any phenolic resin which has bled out of the part into the beaded areas.
2. Open all clogged or closed vacuum holes in the beaded areas of the tool.
3. Wipe beaded areas with a cloth saturated with parting agent.
4. Clean any parting agent from the clamping surfaces of the tool with trichloroethylene.
5. Place a clean sheet of aluminized film on a flat table and apply parting agent with a soft clean cloth to the film area within a periphery line four inches outside of the outer beads.
6. Place the film (Fig. 3-A) in position over the mold (Fig. 3-B) (parting agent side down) and secure in place with a vacuum ring (Fig. 3-C).
7. Apply vacuum and release vacuum ring hold down clamps where necessary to allow film to pull down into mold (see Fig. 4).
8. Form the film into the beaded area by heating with a heat gun (see Fig. 4).
9. Clean the bottom of all beads with isopropyl alcohol; then apply aluminized film adhesive-backed tape to the bottom of all beads. Keep tape taut to avoid wrinkles.

FIGURE 3. INTERNAL FILM PRIOR TO FORMING

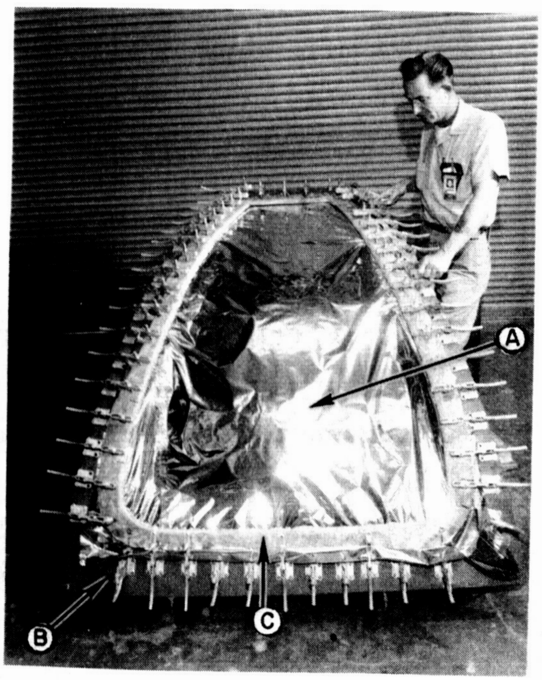
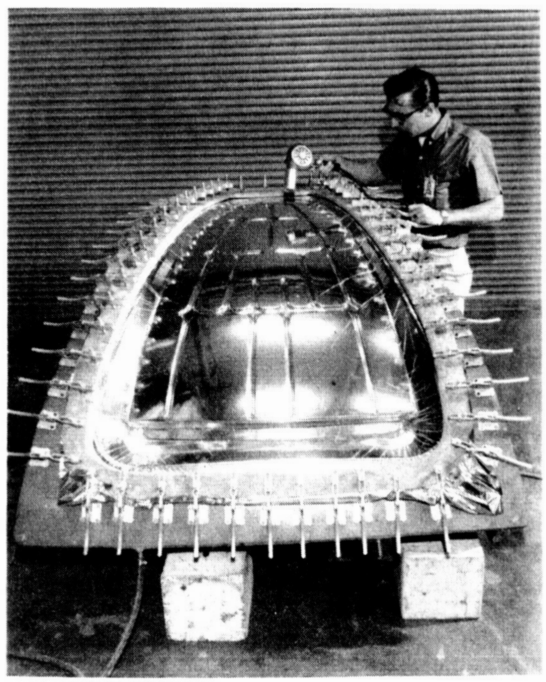


FIGURE 4. INTERNAL FILM AFTER FORMING



DISCUSSION (contd)

Layup of Preimpregnated Phenolic Glass Fabric (Prepreg)

1. Leave formed aluminized film in mold with vacuum on and gently wipe surface of film with clean, soft cloth dampened with alcohol.
2. Cut layers of prepreg cloth and apply first layup as required (Fig. 5).
3. Apply second layer of prepreg (Fig. 6).
4. Slit fabric along beaded areas to allow fabric to conform to surface configuration (Fig. 6).

FIGURE 5. FIRST PLY OF REINFORCED PLASTICS LAYUP

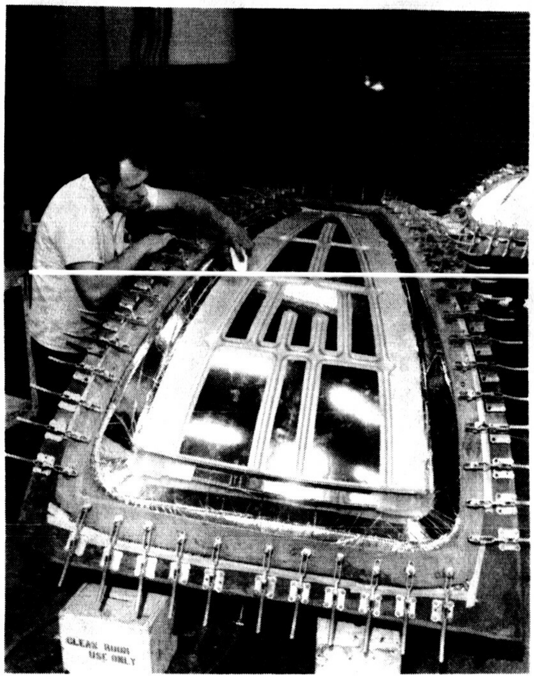
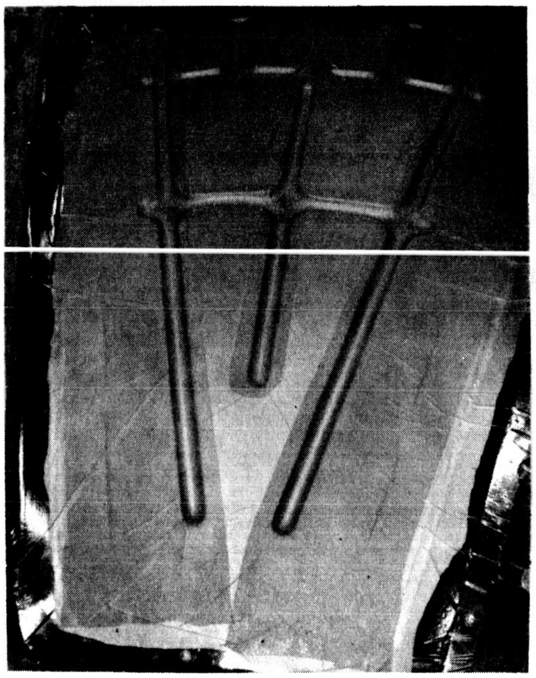


FIGURE 6. SECOND PLY OF REINFORCED PLASTICS LAYUP (Beaded areas slit and formed)



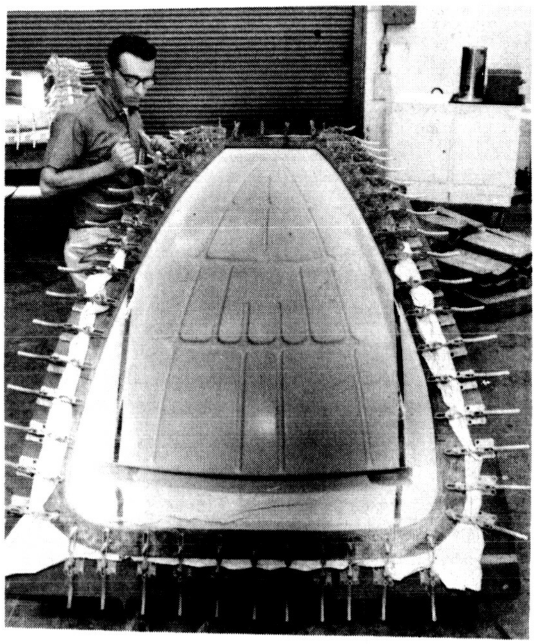
Forming of Polyvinyl Fluoride Film (PVF)

1. Pinpoint puncture through prepreg fabric and aluminized film in bead radius every three inches, starting at one end of the bead to allow escape of gases during oven cure.
2. Cut sheet of PVF to rough size of mold. Gently wipe the side of the PVF film to be bonded with an alcohol-dampened cloth.
3. Tape the aluminized film to the mold around the outside of the vacuum ring with masking tape. This is done so that vacuum ring may be removed for use on PVF film.
4. Remove vacuum ring from tool.
5. Hold PVF film over prepreg in mold and tape so that no wrinkles occur on film surface. Holes may be put in PVF film at deep draw area to retard vacuum action. These holes may be closed with tape when it is necessary to draw a vacuum on the part.

Forming of Polyvinyl Fluoride Film (PVF)

6. Put vacuum ring in position and clamp around periphery of mold.
7. Allow vacuum to draw PVF into mold and release clamps as necessary to allow film to enter mold with minimum amount of wrinkling. A heat gun (500°F) may be used to assist in drawing PVF film to the bottom of the beads. (Fig. 7)
8. Clean PVF surface prior to oven cure by gently wiping with cloth saturated with isopropyl alcohol.

FIGURE 7. EXTERNAL FILM FORMED AND READY FOR OVEN CURE



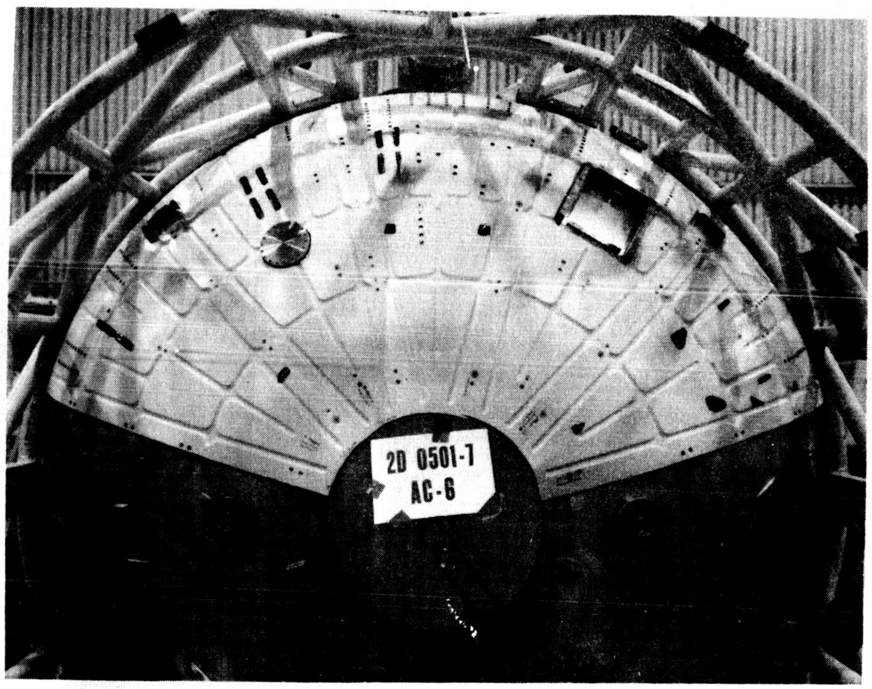
Oven Curing of Forming Part

1. While the formed part (aluminized film, prepreg, PVF) is under vacuum in the mold, place the mold in an oven and cure for 50 to 60 minutes at 340° $\pm$ 10°F or 90 to 105 minutes at 300° $\pm$ 10°F.
2. Remove mold from oven and maintain vacuum until the mold has cooled to a temperature of less than 150°F.
3. While wearing nylon gloves, remove the part from mold and trim to size. Always handle part with nylon gloves, using care not to damage surfaces, abrade edges, or break the part.
4. Clean PVF film surface by wiping with clean soft cloth saturated with isopropyl alcohol.
5. Carefully remove any phenolic resin from the aluminized film surface; then clean film surface using a non-soapy glass cleaner and a soft clean cloth.
6. Place completed parts between sheets of brown wrapping paper prior to placing in a container.

RESULTS

This development program resulted in the fabrication of successful lightweight radiation shields for Centaur AC-6 (see Fig. 8).

FIGURE 8. FIVE (OF TWELVE) RADIATION SHIELD GORES ON AFT BULKHEAD



VALUE ANALYSIS

The value of this project lies in the improved quality of the product and the impressive weight reduction of 16 lbs for this system. The 16 pounds add up to a cost savings of approximately $160,000 per missile.

ACKNOWLEDGEMENTS

Appreciation is extended to the following people for their help and cooperation during this project.

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Department 450-00

Supervision and all other who worked on this project.

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